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GB-A- 2 187 951
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EP 0 310 439 B1

Description

This invention arises out of a research programme conducted on the Applicant's behalf by the Institute for Bioengineering of Brunel University (of Uxbridge, Middlesex, UB8 3PH England), whose contribution is gratefully acknowledged.

The invention relates to sprinklers for fire protection.

The essential functions of a fire sprinkler are to detect and react to radiant and/or convective heat attributable to fire conditions (without reacting to innocuous heat, such as from the sun) and to distribute extinguishing fluid (usually water) over the whole area protected as soon as possible after fire conditions arise and certainly before the air movements caused by the fire are strong enough to blow the extinguishing fluid away.

Current sprinklers are of two classes; one relies on the use of a glass bulb which shatters due to generation of pressure by heating of a liquid within to release extinguishing fluid; the other uses a mechanical valve, biased open by a spring but retained closed by a link of a low-melting solder alloy. In both cases the response speed is restricted by the fact that the detecting material (the fluid and the solder alloy respectively) cannot (or at least cannot readily) be exposed directly to the radiant heat of a fire, owing to the need to have a fluid distributor downstream of (usually below) the fluid exit, and by the fact that it is necessarily in good thermal contact with the metal body of the sprinkler, with a pipe system and with fluid therein, which have a significant combined thermal capacity.

Proposals have been made for a sprinkler which comprises a flow passage extending from an inlet to an outlet, a fluid distributor positioned beyond the outlet, a frangible member closing the flow passage, and separate temperature-responsive means for shattering the frangible member to allow passage of fluid on detection of predetermined temperature-rise conditions (for example GB-A 2 187 951).

These proposals make possible a new class of fire sprinkler in which the heat detecting element can be directly exposed to radiant as well as convective heat, can have a large exposed area for maximum heat gathering, and can be thermally insulated by use of polymeric, ceramic or vitreous material as the circumstances of the installation require; it also makes possible designs in which the heat detecting element can be removed and replaced, either for testing or as a precaution against ageing, or in order to change the sensitivity of the sprinkler (eg when the materials stored in a warehouse change) without cutting off the supply of fluid and therefore without needing to disable more than one sprinkler at a time; but known temperature responsive shattering means have been complex and therefore of uncertain reliability, and have involved use of pyrotechnic devices (e.g. GB-A 2 187 951, GB-A 700 139) or electric heating (e.g. GB-A 864 384) to provide the energy and generate the force required to shatter the frangible member.

The sprinkler in accordance with the invention is of this class and is characterised by the fact that the shattering means comprises a temperature-responsive element of a shape-memory alloy, such as the nickel-titanium one, which by itself supplies energy required to shatter the said frangible member.

Preferably the alloy is in sheet or other extended form for maximum heat uptake. A particularly preferred form is that of a sheet distorted into a dome and recoverable towards (ideally to) a flat sheet form: this is capable of generating ample force. It can be treated (by coating, etching or the like) to enhance the thermal emissivity of its surface.

Preferably the fluid distributor is located between the outlet and the temperature-responsive element, so that the latter may be fully exposed to the area to be protected.

In this case the heat-responsive element may effect shattering of the frangible member by directly acting on an elongate ram or other thrust member extending through an aperture in the central part of the water distributor, but other mechanisms could be used.

It is normally desirable that the shattering means applies no substantial force to the frangible member unless and until the heat-responsive element is actuated by the occurrence of the said predetermined temperature-rise conditions.

The frangible member may be of glass or ceramic material, or of other material of a suitably rigid and brittle nature. It may be a flat or domed disc, but it could take other forms, for example a tube. In appropriate cases, it may be heat-treated, scored or otherwise processed to ensure a distribution of locked-in stresses that is conductive to shattering into small pieces which cannot seriously impede fluid flow.

When the frangible member is of ceramic, the thrust member may be made in one piece with it; when separate, the thrust member is preferably made of or tipped with a material harder than the surface of the frangible member.

Then the frangible member is a disc, it is preferably sealed to the body of the sprinkler without gripping its edges.

The body of the device may be of brass, in which case the temperature-responsive element is preferably thermally insulated from it by spacers (e.g. washers) of polymeric material, ceramic or glass. Alternatively, however, the body itself may be made wholly or partly of a suitably tough vitreous or ceramic material (in which case it may be possible for the frangible member to be made in one piece with it), or (for use in installations where the risk of flame directly impinging on the sprinkler before it operates can be discounted) of a suitable polymeric material. A thermoplastic material can be used provided its softening temperature is well above the response temperature of the temperature-responsive element, but thermosets may be preferred. In either case, fire-retardant grades may be recommended. Apart from the ad-

vantage of inherent thermal insulation, a polymeric body is more suited to aesthetic design treatment and can be self-gasketing and less expensive than a metal body. Creep resistance is not required, because the temperature-responsive mechanism can be designed to impose no forces on the body in the quiescent state.

The invention will be further described, by way of example, with reference to the accompanying drawings which show various designs of prototype sprinkler in accordance with the invention.

In the drawings:

Figure 1 is a longitudinal (vertical) section through a first prototype;
Figure 2 is an underneath plan view of the first prototype;
Figure 3 is a partial elevation in the direction of the arrows III, III in figures 1 and 2;
Figure 4 is a fragmentary cross -section on the line IV-IV in figure 2;
Figure 5 is a side elevation of the shape-memory alloy actuator used in the first and several other prototypes;
Figure 6 is an underneath plan showing one way in which the first prototype could be treated as an aesthetic feature in a suspended ceiling installation;
Figures 7–11 and 13–19 are longitudinal (vertical) sections each through a different prototype; and
Figure 12 is an underneath plan view of a one-piece frangible body and actuating member used in the design of Figure 11.

The prototype sprinkler of figures 1–6 comprises a body 1 of brass or other suitable metal with an external screw thread 2 for screwing to a fluid supply pipe in the usual way. The inlet 3 is at the upper end of the body (in its usual orientation, as shown) and the outlet is at its lower end and closed by a frangible glass disc 4. This is secured in a fluid-tight manner by a metal collar 8 screwed into a thread cut inside the body and acting through a sealing ring 9 of a hard plastics material such as nylon 66 which is stepped so as to bear on the glass disc and thus seal it to the body without gripping its edges, as a precaution against broken pieces remaining gripped and not falling away. Many other plastics materials are suitable for making the sealing ring e.g. acetal polymers, polyether sulphones, polyether ketones, polycarbonates, acrylics, nylon 6, nylon 11 and the material sold under the trademark Delrin.

Beyond the outlet is a water-deflector 5 (fluid distributor) supported by a pair of legs 6, 6 from a ring 7 screwed to the body 1. The water deflector 5 (fluid distributor) (made of any suitable plastics material, or of metal, in which case it could be made in one piece with legs 6 and ring 7) also acts as a guide for a hardened steel pin serving as a thrust member 10 which rests loosely on an actuator element 11 (temperature responsive element) of a shape-memory alloy. This is supported by four claws 12 (best seen in figures 2–4) depending from the legs 6 so as to have a large exposed area and relatively little heat-conducting contact.

Figure 5 shows the shape of the shape-memory alloy element, which is made from niickel-titanium shape-memory alloy-sheet 0.5 mm thick-heat treated for 1 hour at 500°C while clamped flat and then, after cooling, domed to a height of 1.2 mm by pressing centrally with a steel ball 12 mm in diameter while clamping the edges. Domed actuator elements made in this way recover to a nominally flat shape at a temperature in the region of 70°C and in doing so generate large forces if restrained: we have observed forces up to 57.7 kg weight (556N).

While discs of any ordinary glass can easily be broken by the available force, it has been found that reliable shattering into small pieces that will not impede the flow of water is greatly assisted by the use of glass with large locked-in stresses – Best results to date have been obtained with glass supplied by Corning Glass Works of Corning, NY 14830 USA under their identification code 0313. This is a glass strengthened (and thus made more brittle) by sodium-ion exchange, used mainly for aircraft windows and tape-reel flanges; according to the manufacturer's data, it has a density of 2.46 kg/m^3, Youngs Modulus 7×10^4 MN/m^2, Poisson's Ratio 0.22, Shear Modulus 2.9×10^4 MN/m^2, Modulus of Rupture (abraded) 300 MN/m^2 and Knoop Hardness (at 100 g load) 5780 MN/m^2.

This glass was supplie!d in discs 22.2 mm (7/8ths of an inch) in diameter and 2.1 mm (1/12th of an inch) thick. Its extreme surface hardness makes it advisable to use a thrust member made of or tipped with, a very hard material (e.g. tungsten or a hard ceramic such as alumina or zirconia): hardened steel thrust members are liable to bend rather than penetrate the surface.

Another suitable glass (which is less hard and can be used with hardened steel actuator members) has built-in stresses resulting from a heat-treatment substantially the same as used for toughened glass windscreens and is available from Pilkingtons (New Business Development Unit) Limited of St Helens, Merseyside, England in the form of discs 22 mm in diameter and nominally 2 mm thick.

As seen, by way of example, in figure 6, the sprinkler design lends itself to aesthetic treatment by placing it behind a ceiling tile 16 with a central aperture 17 through which the disc 11 (temperature responsive element) and little else is visible and a ring of apertures 18 through which water can flow when necessary (and by which it may be deflected if desired.)

The prototype of figure 7 is identical in principle to the one of figures 1–6, but its major structural components 1,6/7 and 8 are redesigned for fabrication in a suitable plastics material (such as filled polyamide or polyimide, polysulphone, polyetherketone, or polyether.)

In the prototype design of Figure 8, the fluid passage extends from inlet 3 to an outlet closed by a frangible glass disc 4 sealing in this case conjunction with a simple washer 21 (e.g. of PTFE) and a body 22 of the upper part 23 of which takes the form of a gland nut.

The lower part 24 of the body is shaped to form a distributor for the water (or other fluid) that will impinge on it if the disc 4 is shattered and also to accommodate an actuator element 11 in the same general form as before. The element 11 is secured by a circlip 25 and loosely supports the thrust member 10. A pair of ceramic rings 26 provide thermal insulation between the temperature-responsive element 11 and the body 22.

In a particular series of prototypes made in accordance with figure 8, the frangible discs 4 were 1.0 mm thick and 20 mm in diameter, and were cut from soda-glass microscope slides using a diamond-tipped shell cutter (designed for cutting holes in flat glass). Discs that did not evidence internal stresses on examination under polarised light were rejected. As a further precaution against the discs breaking into large pieces that might obstruct the flow of fluid, they were scored by adhering them to the faceplate of a lathe and using a diamond tip glass cutter mounted in guides and subjected to light hand force in a concentric circle 18 mm in diameter. The washer 5 was of PTFE and was 0.5 mm thick and the thrust member 10 was of hardened steel and 2 mm in diameter.

The shape-memory actuator element 11 was made from 0.5 mm thick nickel-titanium shape-memory alloy sheet heat-treated for 30 minutes at 440°C while clamped flat, quenched into water and domed by cold-drawing until its height was 2.75 mm. Recovery temperature was about 70°C.

The sprinkler shown in Figure 9 is similar to that of Figure 8 except that the body part 30 can be unscrewed without disturbing the mounting of the frangible disc 4, to allow the shape-memory temperature-responsive element 11 to be removed and replaced as desired. In designs for public-access buildings, a secure key-operated connection can be substituted for the simple screwed one shown.

Figures 10–14 illustrate a series of alternative designs using frangible members of ceramic material instead of glass.

In the sprinkler of Figure 10, the frangible member 40 comprises a flat disc 41 weakened around its periphery by a groove 42 and mounted in the outlet of the body 1 by an integral collar 43 and an O-ring seal 44; the thrust member 45 is also made in one piece with the frangible member. The composite frangible ceramic member may be made by isostatic pressing from slurry of any appropriate technical ceramic, or may be machined from one of the machinable ceramics, e.g. the one sold by Aremco Products Ind of P.O. Box 429 Ossining NY 10562, USA under the trademark "Aremcolox" or the "machinable glass ceramic" sold by Corning Glass Works under the trademark "Macor".

Figures 11 and 12 show a modification of this design in which the frangible ceramic member 40 is machined and is weakened by a turned groove 41 and a plurality of milled blind bores 42. In this case, a polymeric gasket 43 is used for sealing.

Figure 13 shows another modified version of the design of figure 10 in which the body parts (1, 6, 7) also are made of ceramic material.

Figure 14 shows another variation in which the frangible member 40 is domed.

Figure 15 shows a modification of the design of figure 1 in which the thrust member 50 is bifurcated. This is designed to comply with the current conventional requirement for a sphere of specified size to pass freely through the water passage of a sprinkler after actuation.

Figure 16 illustrates another modification for the same purpose in which the thrust member 51 is eccentrically positioned. This necessitates the use of a separate water-deflector plate 52 to restore a symmetrical water distribution.

Figure 17 shows another design, in which the temperature-responsive shape-memory element 11 is placed much closer to the frangible disc 4 and acts on it through a ring 53; a central aperture 54 through the element allows the water (or other fluid) to pass freely through to the distributor 55 after the disc 4 has shattered. In this design it is desirable for the body, or at least the fluid distributor 15, to be made of a material (such as silica glass) that transmits a substantial part of the infra-red wavelength range, in order to avoid insensitivity to a fire breaking out immediately below the sprinkler.

Figure 18 shows another variant design (not a recommended one, especially for applications in which sensitivity to radiant heat is required) in which the frangible member 58 is tubular and the temperature-responsive element is a ring 59 of a shape-memory alloy which reduces in diameter on recovery.

Samples of certain prototypes were subjected to tests in accordance with the procedures set out by the Loss Prevention Certification Board of Melrose Avenue, Boreham Wood, Hertfordshire WD6 2BJ England, in Loss Prevention Standard LPS 1039: Issue 2:6:4:87 entitled Requirements and Testing Methods for Automatic Sprinklers, except that in the tests requiring a wind tunnel, the tunnel was not of the dimensions specified but was rectangular with a cross-section 70 x 90 mm.

These tests used predominantly (forced) convective heating, in order to establish performance under worst conditions. The tests applied were as follows:

1. In a water-bath test according to Section 7.4 of the Standard the nominal release temperature of the prototype were measured.
2. Performance was compared with conventional sprinkler designs in the 'plunge test' of Section 8.5.1 of the Standard.

3. In a rate-of rise test following section 8.3.2 of the Standard, samples were mounted in a tunnel through which air was blown. the air temperature being steadily raised by electric heaters.

Time of actuation and the corresponding temperature were recorded and the rate-of-rise time constant τ calculated

The Prototypes tested were as follows:

Prototype A: According to figure 1.

Prototype B: As Prototype A, except that the actuator disc was held by a continuous rim instead of the four claws 12.

Prototype C: Intermediate between Prototypes A and B, formed by milling a single slot through the rim rather them the two slots required to form the claws 12.

Prototype D: According to figure 8. except that the thrust member was flat topped.

In the water-bath test:, the nominal release temperature of Prototype B WclS found to be 50.3°C (for comparison, a standard glass bulb sprinkler with a declared release temperature of 68°C was tested and gave a value of 72°C, and a fusible link sprinkler gave a value of 75.8°C)

In the plunge test, in which the measured air temperature ranged from 194 to 198°C, response times (in seconds) were as follows:

TYPE	ORIENTATION	RESPONSE TIME
Prototype A	A	5.6
Prototype A	A	7.2
Prototype B	A	10.6#
Prototype B	N	11.7
Prototype B	N	11.9
Prototype C	A	14.3
Prototype C	A	12.3
Prototype C	A	15.0#
Prototype C	N	6.8
Prototype C	N	4.9
Prototype D	N	25
Prototype D	H	22
and for comparison		
Glass bulb	N	35.2
Glass bulb	N	32.8
Glass bulb	N	33.1
Glass bulb	N	43.
Glass bulb	N	53.
Glass bulb	H	38
Fusible link	A	5.0
Fusible link	N	4.1
Fusible link	N	21

A = pendant with support legs aligned with gas flow.

N = pendant with support legs normal to gas flow.

H = horizontal

These samples actuated with violent snap action, presumably because of unintended restraint at the edges of actuator disc

The " τp " factor of Prototype D was calculated as 79 compared with 67 for the third fusible link sample and 169 for the fourth and fifth glass bulb samples.

In the rate-of-rise test, made with Prototype D only, using a rate of rise of air temperature of 7.5°C/min (nominal), a first sample operated after 10 minutes 42 secs at an air temperature of 93°C; a second sample after 9 minutes 34 seconds at 92°C. When the rate of rise was increased to 14°C/min, operalion occured after 6 minutes 53 secs and at 110°C at 20°C/min, one sample operated after 5 minutes 8 secs at 121°C and another 5 minutes 39 secs at 128°C. From these measurements, the rate-of-rise time constant τ was estimated at 2.35 minutes.

Claims

1. A fire sprinkler comprising a flow passage extending from an inlet (3) to an outlet, a fluid distributor (5) positioned beyond the outlet, a frangible member (4) closing the flow passage, and separate shattering means (10, 11) for shattering the frangible member (4) to allow passage of fluid on detection of predetermined temperature-rise conditions, characterised in that said shattering means (10, 11) comprises a temperature-responsive element (11) of a shape-memory alloy which by itself supplies the energy required to shatter the said frangible body (4).

2. A sprinkler as claimed in Claim 1 in which the shape-memory alloy (11) is in sheet; or like extended form.

3. A sprinkler as claimed in claim 1 in which the shape-memory alloy (11) in the form of a sheet distorted into a dome and recoverable towards a flat sheet.

4. A sprinkler as claimed in any one of the preceding claims in which the fluid distributor (5) is located between the outlet and the temperature-responsive element (11).

5. A sprinkler as claimed in any one of the preceding claims in which the frangible body (4) is a disc and is heat-treated, scored or otherwise processed to ensure a distribution of locked-in stresses conducive to shattering into small pieces.

6. A sprinkler as claimed in any one of the preceding claims comprising a metal body (1) and in which the temperature-responsive element (11) is thermally insulated from the metal body.

7. A sprinkler as claimed in any one of claims 1–5 having a body (1) made wholly or partly of a vitreous or ceramic material.

8. A sprinkler as claimed in any one of claims 1–5 having a body (1) made wholly or partly of a polymeric material.

9. A sprinkler as claimed in claim 8 in which no substantial forces act on the body or body part of polymeric material unless and until the temperature-responsive element (11) is actuated by the occurence of the said predetermined temperature-rise conditions.

10. A building protected from fire by an installation comprising a plurality of the sprinklers claimed in any one of the preceding claims.

11. A sprinkler as claimed in any one of claims 1–9 in which the frangible member (4) is a disc and is sealed to the body of the sprinkler without gripping its edges.

12. A sprinkler as claimed in any one of claims 1–9 characterised in that the said shattering means can be removed and replaced without cutting off the supply of fluid.

Patentansprüche

1. Löschbrause mit einem Flußdurchgang, der sich von einem Einlaß (3) zu einem Auslaß erstreckt, einem Fluidverteiler (5), der unterhalb des Auslasses angeordnet ist, einem Sollbruchglied (4), das den Flußdurchgang verschließt, und einer getrennten Brecheinrichtung (10, 11) zum Zerbrechen des Sollbruchgliedes (4), um den Durchgang eines Fluids nach dem Feststellen von vorbestimmten Temperaturanstiegsbedingungen zu gestatten, dadurch gekennzeichnet, daß die Brecheinrichtung (10, 11) ein auf Temperatur ansprechendes Element (11) aus einer Formerinnerungslegierung aufweist, welche aus sich selbst heraus die Energie zur Verfügung stellt, die zum Zerbrechen des Sollbruchgliedes (4) erforderlich ist.

2. Brause nach Anspruch 1, wobei die Formerinnerungslegierung (11) zu einem Blech oder einer ähnlich ausgedehnten Gestalt geformt ist.

3. Brause nach Anspruch 1, wobei die Formerinnerungslegierung (11) die Gestalt eines Blechs aufweist, das zu einer Kuppel verformt ist und in ein flaches Blech rückverformbar ist.

4. Brause nach einem der vorangegangenen Ansprüche, wobei der Fluidverteiler (5) zwischen dem Auslaß und dem auf Temperatur ansprechendem Element (11) angeordnet ist.

5. Brause nach einem der vorangegangenen Ansprüche, wobei das Sollbruchglied (4) eine Scheibe ist und wärmebehandelt, gekerbt oder auf andere Weise behandelt wird, um eine Verteilung von eingebauten Spannungen zu gewährleisten, die zum Zerbrechen in kleine Stücke führen.

6. Brause nach einem der vorangegangenen Ansprüche mit einem Metallkörper (1) und wobei das auf Temperatur ansprechende Element (11) thermisch vom Metallkörper isoliert ist.

7. Brause nach einem der Ansprüche 1 bis 5 mit einem Körper (1), der ganz oder teilweise aus einem gläsernen oder einem Keramikmaterial hergestellt ist.

8. Brause nach einem der Ansprüche 1 bis 5 mit einem Körper (1), der ganz oder teilweise aus einem Polymermaterial hergestellt ist.

9. Brause nach Anspruch 8, wobei keine wesentlichen Kräfte auf den Körper oder das Körperteil aus Polymermaterial einwirken, wenn nicht und bis das auf Temperatur ansprechende Element (11) durch Eintreten der vorbestimmten Temperaturanstiegsbedingungen betätigt wird.

10. Gebäude, das vor Feuer durch Einbau von mehreren Brausen nach einem der vorangegangenen Ansprüche geschützt ist.

11. Brause nach einem der Ansprüche 1 bis 9, wobei das Sollbruchglied (4) eine Scheibe und gegen den Körper der Brause ohne Einspannen seiner Kanten abgedichtet ist.

12. Brause nach einem der Ansprüche 1 bis 9, dadurch gekennzeichnet, daß die Brecheinrichtung ohne Unterbrechung der Fluidzufuhr entfernt und ausgetauscht werden kann.

Revendications

1. Extincteur d'incendie comportant un passage d'écoulement s'étendant d'un orifice d'entrée (3) à un orifice de sortie, un distributeur de fluide (5) positionné au-delà de l'orifice de sortie, un élément cassable (4) fermant le passage d'écoulement, et des moyens (10, 11) d'éclatement séparés pour faire éclater l'élément cassable (4) afin de permettre le passage d'un fluide lors de la détection de conditions d'élévation de la température prédéterminées, caractérisé en ce que lesdits moyens d'éclatement (10, 11) comportent un élément (11) réagissant à la température en alliage à effet mémoire qui délivre de lui-même l'énergie nécessaire pour faire éclater ledit corps cassable (4).

2. Extincteur selon la revendication 1, dans lequel l'alliage à effet mémoire (11) est sous une forme de feuille ou sous une forme étendue analogue.

3. Extincteur selon la revendication 1, dans lequel l'alliage à effet mémoire (11) se présente sous la forme d'une feuille distordue en forme de dôme et pouvant revenir à l'état de feuille plate.

4. Extincteur selon l'une quelconque des revendications précédentes, dans lequel le distributeur de fluide (5) est situé entre l'orifice de sortie et l'élément (11) réagissant à la température.

5. Extincteur selon l'une quelconque des revendications précédentes, dans lequel le corps cassable (4) est un disque et est traité à la chaleur, entaillé ou traite d'une autre façon afin de garantir une distribution des contraintes internes amenant l'éclatement en petits morceaux.

6. Extincteur selon l'une quelconque des revendications précédentes, comportant un corps métallique (1) et dans lequel l'élément (11) réagissant à la température est thermiquement isolé du corps métallique.

7. Extincteur selon l'une quelconque des revendications 1 à 5 ayant un corps (1) fait complètement ou partiellement en un matériau vitreux ou céramique.

8. Extincteur selon l'une quelconque des revendications 1 à 5 ayant un corps (1) fait complètement ou partiellement en un matériau polymère.

9. Extincteur selon la revendication 8, dans lequel aucune force substantielle n'agit sur le corps ou sur la partie de corps du matériau polymère sauf si l'élément (11) réagissant à la température est actionné par l'apparition desdites conditions d'élévation de la température prédéterminées et jusqu'à ce que celle-ci se produise.

10. Bâtiment protégé de l'incendie par une installation comportant une pluralité des extincteurs revendiqués dans l'une quelconque des revendications précédentes.

11. Extincteur selon l'une quelconque des revendications 1 à 9, dans lequel l'élément cassable (4) est un disque et est scellé sur le corps de l'extincteur sans agripper ses bord.

12. Extincteur selon l'une quelconque des revendications 1 à 9, caractérisé en ce que lesdits moyens d'éclatement peuvent être retirés et remplacés sans couper l'arrivée de fluide.

Fig.1.

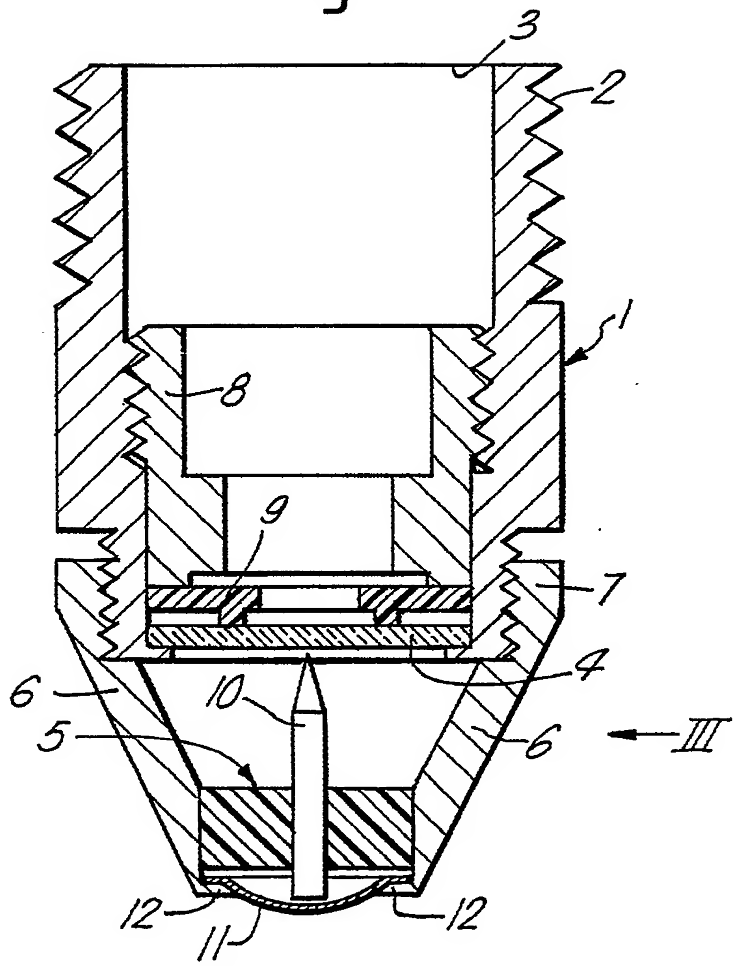


Fig.5.

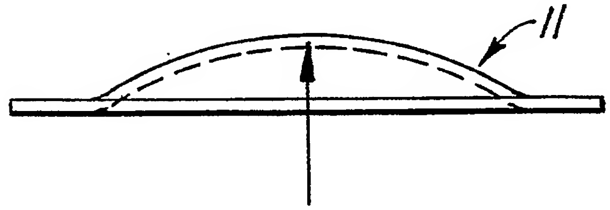


Fig.2.

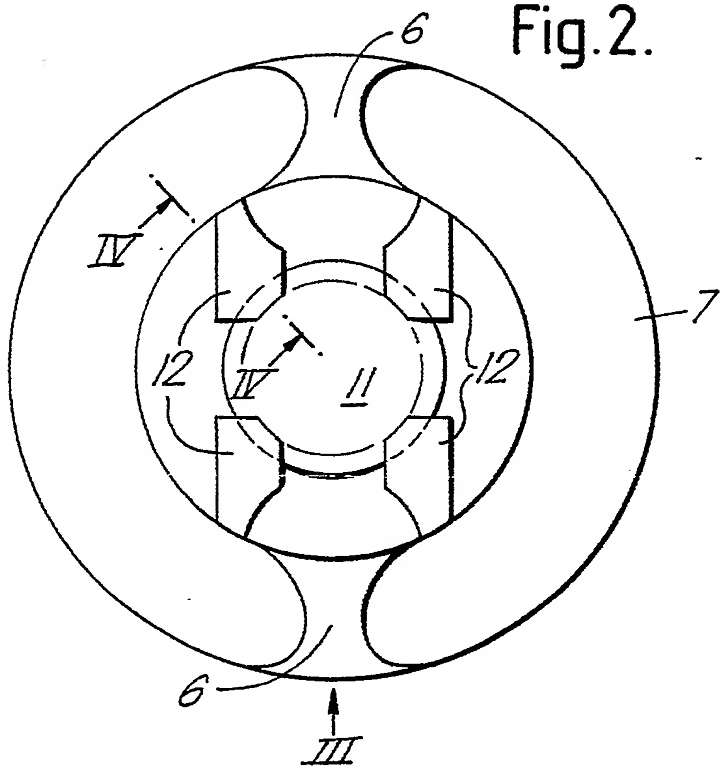
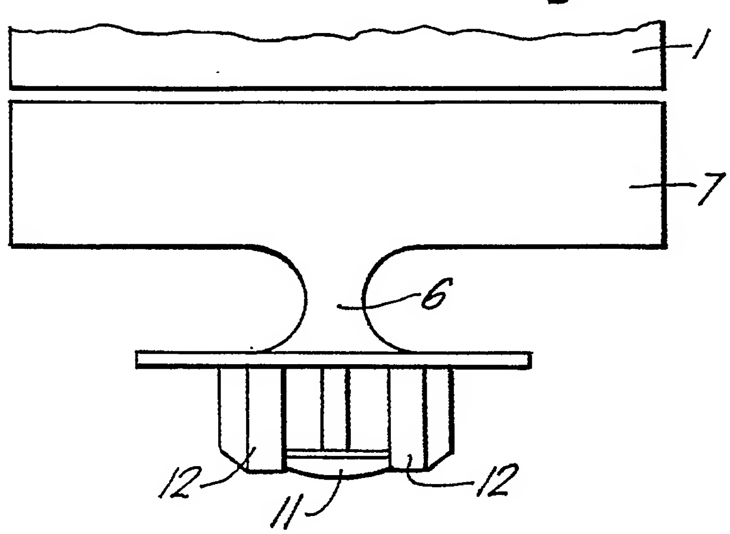


Fig.3.



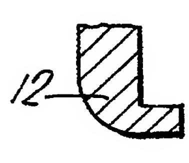


Fig.4.

Fig.6.

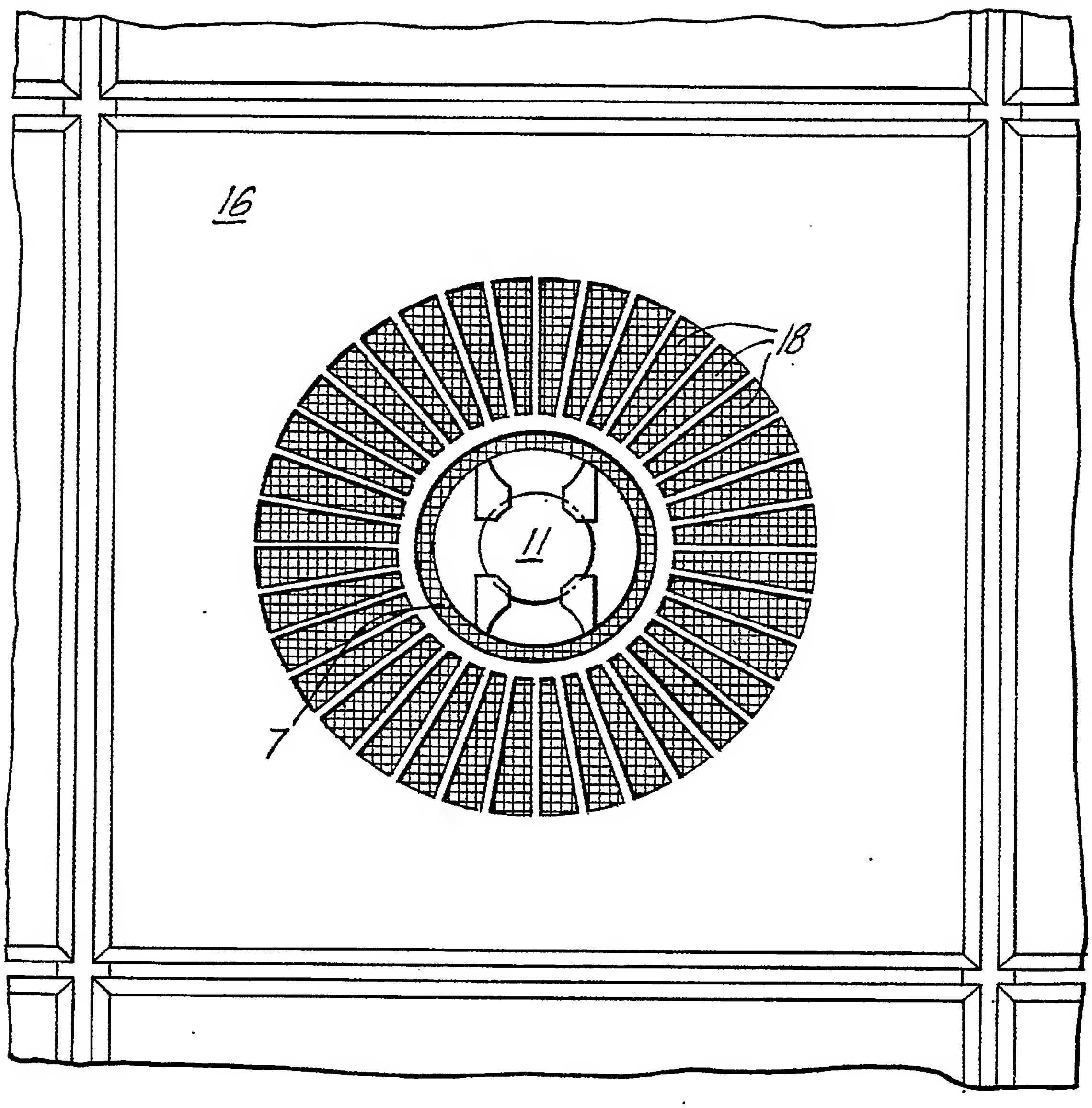
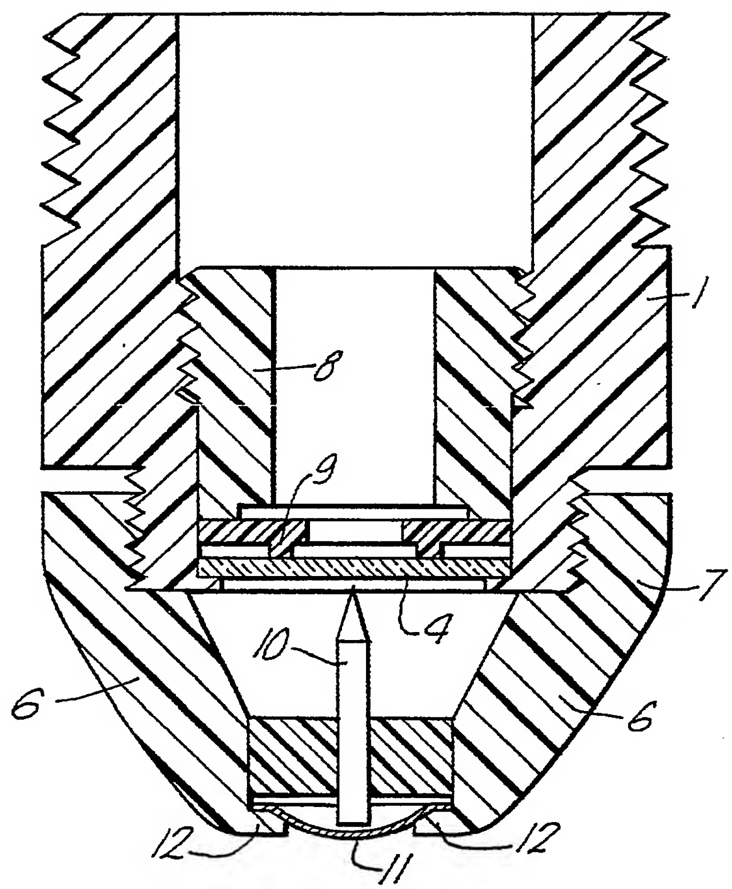


Fig.7.



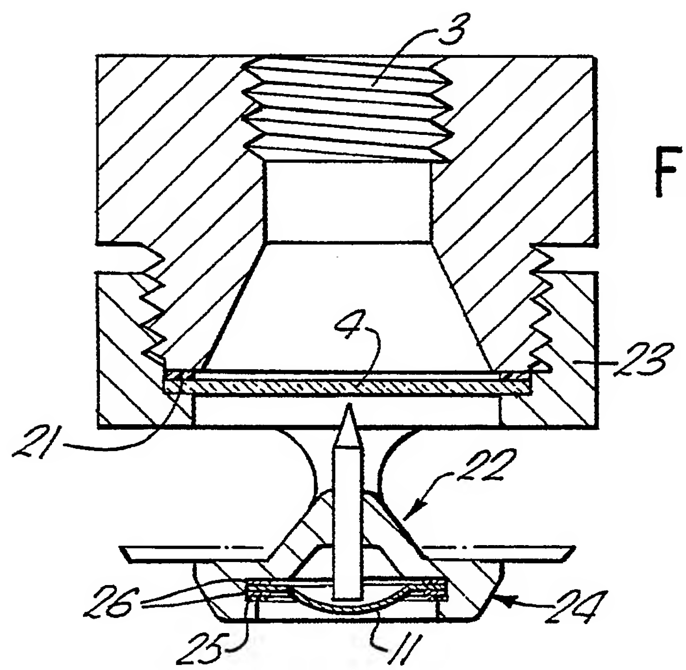


Fig.8.

Fig.9.

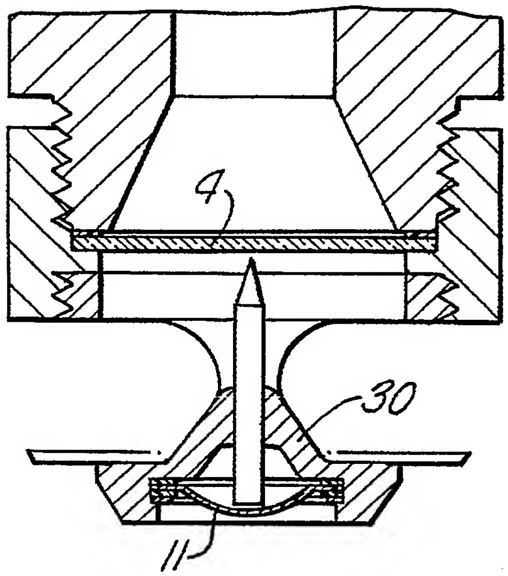


Fig.10.

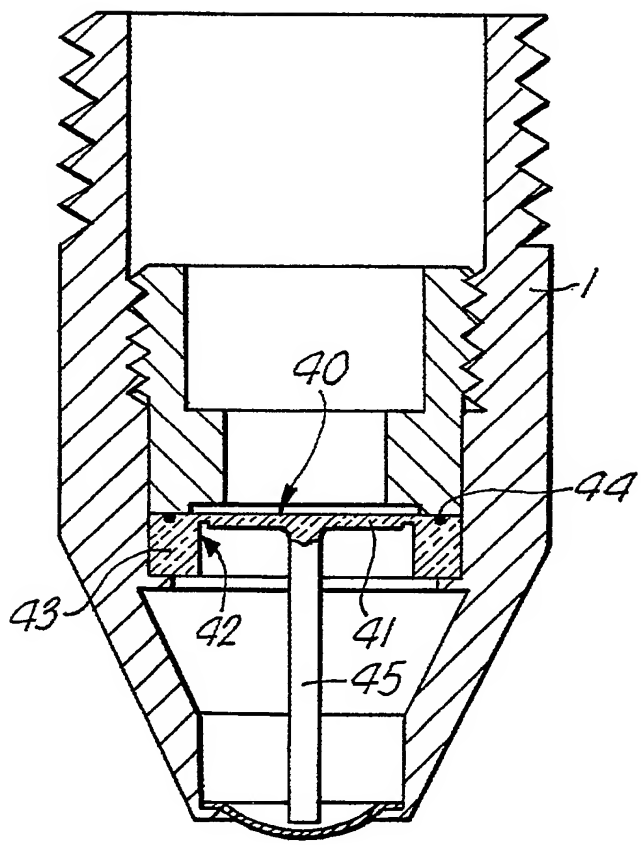


Fig.11.

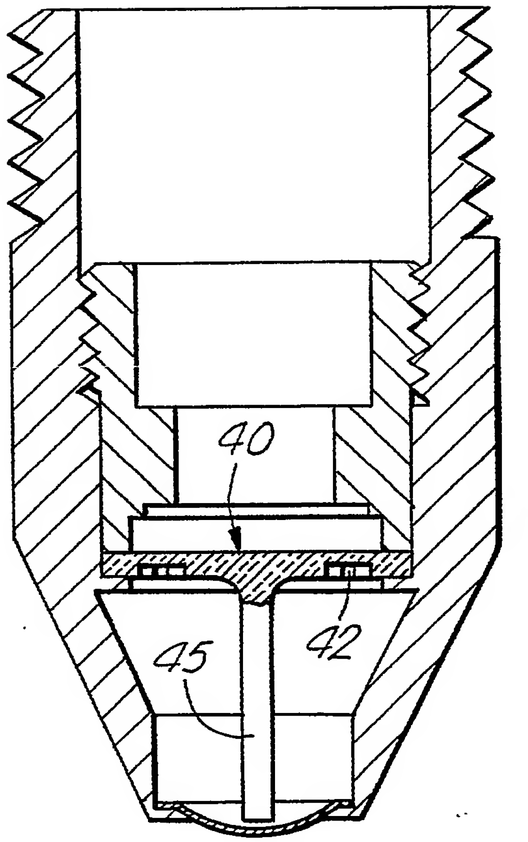


Fig.12.

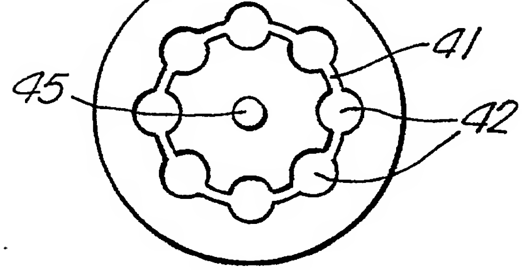


Fig.13.

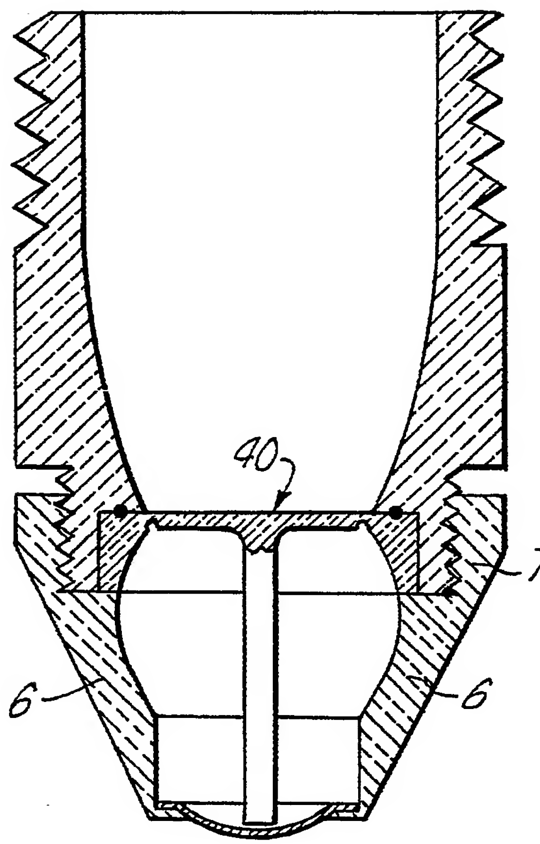


Fig.14.

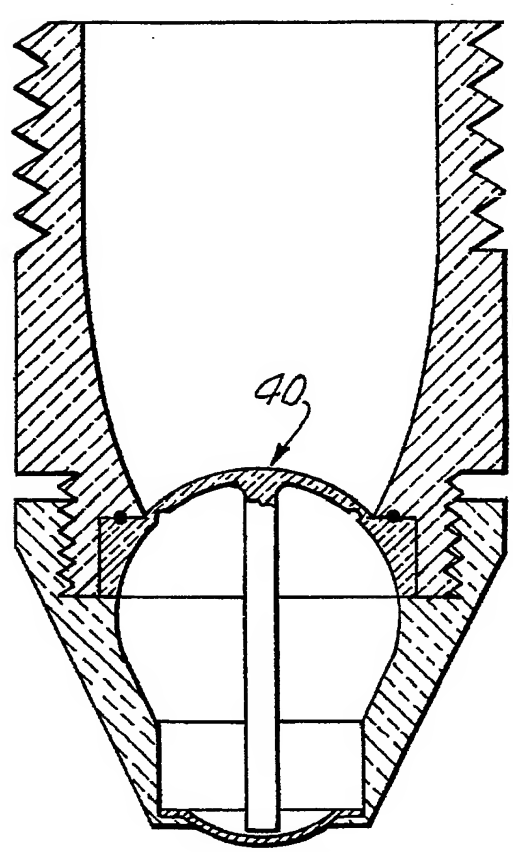


Fig.15.

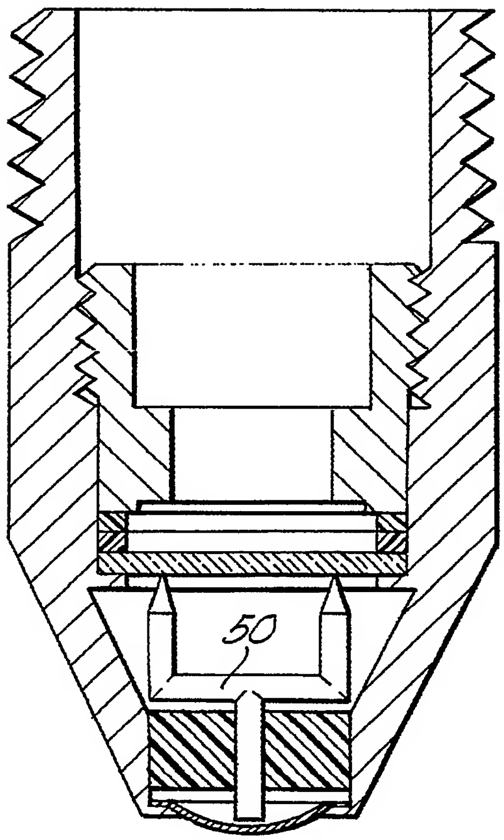
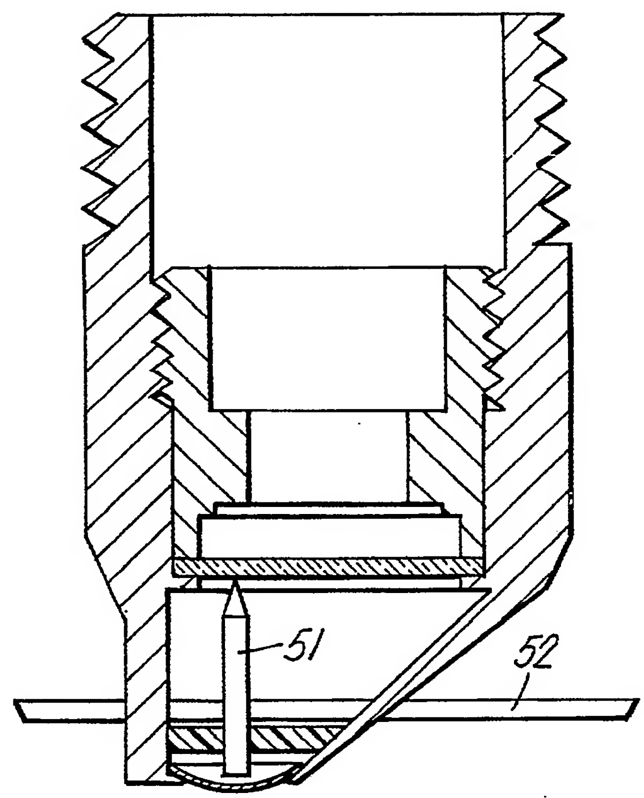


Fig.16.



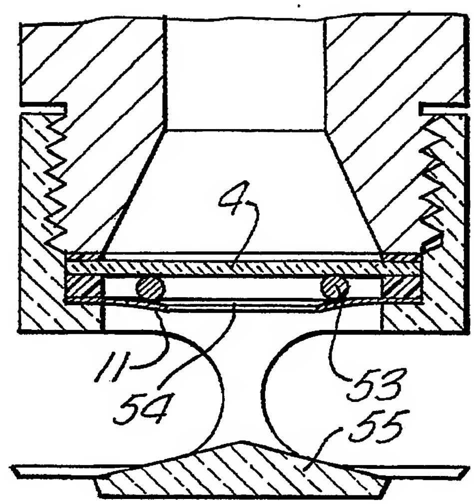


Fig. 17.

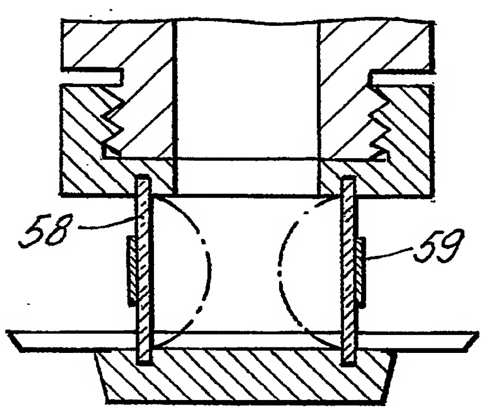


Fig. 18.